Essentials of Marine Biotechnology

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Preface

Seventy percent of the earth's surface is covered by sea, and about 80% of all animal species dwells in the sea. The oceans are where life first began; in the three-billion-year history of the evolution of life, it was only in the range of hundreds of millions years ago when life forms first arrived from the sea to land. Those organisms that arrived on terrestrial represented just a small fraction of all marine creatures, and innumerable others continue evolving independently in the sea to this day. It is therefore explicit that marine organisms are living in the extreme condition and produce unique substances that cannot be produced by terrestrial-based organisms, which can perform multitude of functions for human benefits. Furthermore, sea bearing high-pressure environment, averaging about 380 atm, the marine organisms undoubtedly should possess distinctive mechanisms to withstanding this. With average temperatures of 1–4 °C, seawater is also an optimal environment to inhabit psychrophilic (cold-loving) organisms. Interestingly, the sea floor is also home to organisms with enhanced ability to withstand high temperatures, suggesting even further applications. At the bottom of the seas are hydrothermal deposits where water is discharged at temperatures of over 300 °C.

Considering the existence of such extreme environment, it is well understood that marine biomaterials can be exploited for the benefits of human cause in many ways. These marine organisms hold truly great potential for future applications in marine biotechnology. Marine organisms remain integral to human lives either as an alternative source of protein, natural products, or as potential biomaterial source for industrial purpose. In recent years, rapid advancements in scientific application of marine biotechnology have been witnessed, particularly in the area of natural product development, marine bioenergy, seaweed biotechnology, aquaculture, genomics, cosmeceutical, nutraceuticals, pharmaceutical development, transgenic technology, genetic recombination, cell fusion, and ultrafiltration membranes.

For all various aforementioned reasons, hopes for the future of marine biotechnology and their utilization for the product development for human mankind are increasing ever since the last three decades. However, for the complete development of marine biotechnology, it is important to fully utilize modern-day techniques such as satellites (for positioning of vessels and identifying the area of interest of ocean), advanced robotics system, artificial intelligence, to efficiently

harvest and maintain marine organisms, along with cutting-edge techniques for deep sea exploration.

The book comprises eleven chapters followed by references and comprehensive list of glossary.

Chapter 1 introduces the present, past, and future of marine biotechnology. In this context, some are now predicting that the twenty-first century will more specifically be called the 'marine bio era.' A major factor in this change is the ever-expanding and understanding of previously less-known marine organisms, along with the rapid development of industry-related biological technology.

In Chap. 2, the basic concepts of genetics have been elaborated to comprehend the various aspects of marine biotechnology. It is very much essential to introduce the basics of various aspects of genetics and other related areas to assist in understanding the marine biotechnology. Furthermore, this chapter will also be beneficial for those students who have not taken biology as one of the subjects in their course curriculum.

The recent development of techniques for analyzing large base sequences has led to efforts to decode the genomes of economically and academically important fish varieties. In the fishing industry, decoding of fish genomes is extremely important in three regards: for understanding biological phenomena, use of genome information in selective breeding, and efficient classification of biological resources.

In this regard, Chap. 3 attempts to bring forth the basic understanding of fish genetics, the knowledge of which can be used to restore marine ecosystems by preserving various endangered marine species. Around the world, recent genomic research has been conducted on fish varieties with high economic or industrial value and applied in their breeding or industry use.

Efforts to produce superior, high value-added varieties, using genetic engineering to maximize the productivity over a short time, are underway worldwide. Much research effort has been focused on fish, which have the highest economic value among marine products. Additionally, the introduction of foreign genes from various farmed fish varieties has recently been observed in laboratories in various advanced economies, with investigations underway on gene expression and transmission to future generations. Hence, in the subsequent Chap. 4, the elementary information of fish breeding and along with the application of marine biotechnology has been elaborated in order to maximize the productivity efforts.

Chapter 5 attempts to give an overview of genetic diversity prevailing in marine bio-system along with DNA markers in fish have been elaborated that can play important role in marine farming research and other marine industries involved in sea products. Like agriculture, fish farming subjects organisms to artificial management. In this chapter, emphasis on future genetic improvements to meet ever-increasing demands of marine biomaterials has been discussed that will revolutionize the marine farming research and industry. Furthermore, in this chapter we explained the use of marker in selective marine organism breeding, along with an overview of its method and the current status of research of the field. An account on achievements already made in other organisms has also been elaborated.

Seaweeds are emerging as a future resource with various potential applications for humankind, including food, production of functional substances, and a source for energy and paper-making. Chapter 6 endeavors to fully address the basic culture techniques for seaweed production and their applications. The field of seaweed biotechnology includes a number of different areas, including tissue culture, callus induction, protoplast production and regeneration, cell fusion, and gene manipulation. At the same time, a number of issues remain to be solved, including the failure to achieve full consistency in terminology. Nevertheless, the technology is very important in opening up new possibilities for the use of seaweed not only as a food resource but also for mass production of useful substances or for bioactive substances (cosmeceutical, nutraceuticals, and pharmaceuticals) and biotechnological resources, and greater development is expected for the field going ahead.

Chapter 7 discusses microalgae, a major biological resource for future, particularly in the area of food, cosmetics, energy production, biofertilizer, bioactive substances, and in wastewater treatment. Microalgae, a primary producer in aquatic environments, encompasses a vast biological resource in terms of both volume and variety, with tens of thousands of species producing more than 20 billion tons of organic matter per year. In this chapter, we discussed culture methods of microalgae for mass production; microalgae typically grow far more quickly than land-based plants and can be easily cultured in both freshwater and seawater, or in any environment with light energy. They possess great potential as a material in bio-industry, allowing for low-cost production of industrially useful high-molecular-weight substances such as proteins, fats, sugars, and pigments as well as substances with specific physiological functions.

The development of new and useful materials from marine organisms is a very important field in both academic and industrial terms. Hence, Chap. 8 attempts to address this issue by particular focusing on various aspects of the development of functional materials using marine organisms. This chapter will examine the potential of biomaterial derived from marine organism derived as antibacterial, anti-inflammatory, and anticancer substances that have already garnered attention of pharmaceutical industries. Production and application of mussel adhesive protein are discussed in this chapter. Also, this chapter focusses on various active research efforts currently underway for deriving marine biomaterials for its effectual use in cosmetics, pharmaceuticals, as well as functional foods. Production and applications of marine polysaccharides (chitin, chitosan, chitooligosaccharides, alginate, etc.) in cosmeceuticals, wound healing, and artificial skin development are presented well. A brief explanation has been given the production and pharmacological applications of fish fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

With the recent trend of consistently high oil prices and the climate change agreement taking effect, energy has emerged as a serious societal issue. As a solution to this problem, research into developing and commercializing bioenergy-related technology for the production of clean energy and new/renewable energies using biomass is taking place actively around the world. Therefore, in Chap. 9 we attempt to explain the potential use of marine materials for bioenergy

production. In particular, macroalgae and microalgae can be the alternative sources of biofuels (ethanol, ethane, methane, and other chemical products). Under stable conditions, energy production efficiency is reportedly around ten times higher as compared to land plants. Furthermore, microalgae can be harvested throughout the year and are well suited to automation due to their ease of farming and harvesting. Today, microalgae are drawing global attention as a final means of producing next-generation biofuels. In addition to this, the important key issues are also discussed for the bioenergy production in industrial scale.

Finally, in Chaps. 10 and 11, a comprehensive account on bioactive marine materials has been explained which can be of potential application to treat various human sufferings. In this chapter, bibliographic studies, collection, and surface morphology of marine organism (seaweed, fish, plankton, microorganisms, etc.) are presented well. Detail explanation has been given on isolation techniques for natural product isolation from the marine organisms including analytical techniques (NMR, mass spectra, UV, etc.), chromatographic techniques, separation and fractionation as well as purification techniques. Marine flora and fauna possess outstanding capabilities in producing high-molecular-weight substances and enzymes. Additionally, some species are used as potential producers of enzymes such as deoxyribonuclease, lipase, alginate lyase, protease, agarase, cellulase, and esterase. Numerous bioactive substances have been already derived from marine microorganisms, including those with antimicrobial, antifungal, antiviral, antitumor, anti-inflammatory, antioxidant, and enzyme inhibitors. Even though, mass production of source materials is an issue to that need to be addressed suitably; nevertheless, the beneficial activities from marine microorganisms are enormous.

Nutritional properties of fish, shellfish, algae, and marine microorganisms are generally well known. However, their functional characteristics have not been fully revealed. It is believed that they contain biologically active compounds, including potential nutraceuticals. For example, marine macroorganisms produce a vast array of secondary metabolites including terpenes, steroids, polyketides, peptides, alkaloids, porphyrins, and polysaccharides. These secondary metabolites serve as several pharmaceutical usages (antitumor, anti-inflammation, anti-allergy, antioxidant, antifungal, anti-HIV, and antihypertensive). However, the development of a new drug requires sufficient amounts of pure compounds that exceed by large quantities, but it is extremely difficult to collect them in higher amounts from a marine resource. Moreover, with the respect to investigation and development of marine bioactive substances for industry applications, many studies have been conducted to develop marine biotechnologies, such as membrane bioreactor, bioconversion, and continuous mass producing process technology. The biotransformation technology consisting of membrane bioreactor-assisted bioconversion and continuous mass production made significant contributions to the commercial development of marine nutraceutical and biomedical substance. Even though several biotechnological method improvements have been achieved for the production of commercial materials using marine bioresources, maintaining the raw materials of marine bioresources is a serious warning for marine biotechnology industries. Several difficulties are still existing for the production of larger quantity of marine biomass.

Above all, the biggest problem is that not all the marine biomass resources are produced in huge quantities while industrialization is commonly required huge amount of raw materials for the production commercial products which also should be consistent and availability throughout the year. In order to solve these problems, advanced sea farming technologies are necessary, but there has not been sufficient research and development investment for sea farming industries due to lack of awareness. In addition to this, it is also unfortunate to secure workers for considering the risk of working at sea. With these difficulties, it will not be easy to cultivate marine biotechnology industries, unless investment to be supported for future production of marine biomass. The solution for these issues, new modern technologies such as artificial intelligence robots, drones, submersibles, and automated raw material harvesting vessels in farming industries should be introduced instead of manpower. By including all the above-mentioned technologies, high value-added marine biotechnology industry will be expected to succeed as a world power industry as a Fourth Industrial Revolution.

I am fully aware of the fact that I cannot completely satisfy the interest of various scientists working in this area, but I hope this book will certainly bring forward new avenues in this ever-growing field. In the future, I intend to fully address any inadequacies which may have left inadvertently, and welcome all suggestions that can be included in coming editions. I am thankful to Dr. Venkatesan J, Research Professor, and Dr. Sandeep Kumar Singh, Postdoctoral fellow, who have extended their helping hands to complete this book.

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Prof. Se-Kwon Kim
Distinguished Professor

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In recent years, he recognized the value of under-utilized marine resources and felt the need to develop products through researches that can utilize them more effectively. He invited me as Research Adviser and dedicated himself to publish technical books emphasizing the scientific value of marine life as well as related research.

With his help, this book has been published, providing many readers with the knowledge of how scientific values of marine life can enhance human health.

I would like to thank him sincerely for publishing this book.

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Prof. Se-Kwon Kim
Distinguished Professor

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About the Author

Prof. Se-Kwon Kim, Ph.D. is presently working as Distinguished Professor in Korea Maritime and Ocean University and Research advisor of Kolmar Korea Company. He worked as Distinguished Professor at Department of Marine Bio Convergence Science and Technology and Director of Marine Bioprocess Research Center (MBPRC) at Pukyong National University, Busan, South Korea.

He received his M.Sc. and Ph.D. degrees from Pukyong National University and conducted his postdoctoral studies at the Laboratory of Biochemical Engineering, University of Illinois, Urbana-Champaign, Illinois, USA. Later, he became a visiting scientist at the Memorial University of Newfoundland and University of British Columbia in Canada.

He served as President of the 'Korean Society of Chitin and Chitosan' in 1986–1990 and the 'Korean Society of Marine Biotechnology' in 2006–2007. To the credit for his research, he won the best paper award from the American Oil Chemists' Society in 2002. He was also Chairman for '7th Asia-Pacific Chitin and Chitosan Symposium,' which was held in South Korea in 2006. He was Chief Editor in the 'Korean Society of Fisheries and Aquatic Science' during 2008–2009. In addition, he is Board Member of the International Society of Marine Biotechnology Associations (IMBA) and International Society of Nutraceuticals and Functional Food (ISNFF).

His major research interests are investigation and development of bioactive substances from marine resources. His immense experience of marine bio-processing and mass production technologies for marine bio-industry is the key asset of holding majorly funded marine bio projects in Korea. Furthermore, he expended

his research fields up to the development of bioactive materials from marine organisms for their applications in oriental medicine, cosmeceuticals, and nutraceuticals. To this date, he has authored around 650 research papers, 70 books, and 120 patents.